Operation of PEMFC with Zirconium Hydrogen Phosphate-based Membrane under Low Humidity Conditions

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Recent advances in polymer electrolyte membrane fuel cells (PEMFCs) show the good opportunity for PEMFCs to be used in a variety of fields such as stationary power sources, portable electronics, and vehicles. Considering the status of current fuel cell cost, the application of PEMFCs to small portable power sources is favorable. Much research has been focused on the stack design, catalyst selection, optimization of operation condition, water and heat management, and other parameters that are important to cell operation and power output. For portable application, simplification of fuel cell system is required in order to maximize power density. If PEMFCs can be operated under low humidity or non-humidified conditions, water management will become easier. However, conventional Nafion® membranes used under low humidity or non-humidity conditions will pose a problem of increased internal resistance. The reason for this is that Nafion® membranes require water to maintain their conductivity. The catalyst layers will also suffer from dry-out or lower proton conductivity because of dehydration of Nafion® that binds the catalyst together in the catalyst layers. Obviously, the Nafion® membrane is not a good electrolyte candidate for low or non-humidified operation.

At present, many methods have been proposed to solve the dehydration of Nafion membrane. Two approaches are very typically used: (I) new polymer electrolytes for which conductivity is independent of water retention; (II) modified membranes based on Nafion and an inorganic solid. For the former, some polymer electrolytes show good conductivity but the data for long-term stability under cell operation condition is not available. For the latter, the basic idea is to use solid proton conductors to modify the Nafion® membrane. Inorganic solids[1-2] that have been tried include SiO_2, TiO_2, heteropoly acids and zirconium hydrogen phosphate. Under low humidity condition, these membranes showsimproved conductivity compared to commercial Nafion® membranes because inorganic solids help the membrane retain water and increase proton concentration in the membrane structure. Therefore, these membranes have a good chance to be capable of operation under low or non-humidified operation.

In this paper, composite membranes based on Nafion® and zirconium hydrogen phosphate are reported under low-humidity conditions at different operating temperatures. The preliminary results show that Nafion-Teflon-$Zr(HPO_4)_2$ gives good resistance at 40°C and 50°C under low-humidity condition. Figure 1 shows the effect of humidifier temperature (for both of anode and cathode) on the membrane resistance. With humidifier temperatures of 18°C (corresponding to relative humidity 16.7% at 50°C operation), membrane resistance for Nafion-Teflon-$Zr(HPO_4)_2$ at 50°C is about 0.11Ohm-cm^2. With such a low resistance, the performance loss caused by membrane resistance is not big concern. Experiments will be reported in which the membrane resistance was measured with no humidity at different temperatures, and also the dry-out of Nafion in catalyst layer will be discussed.

Reference:
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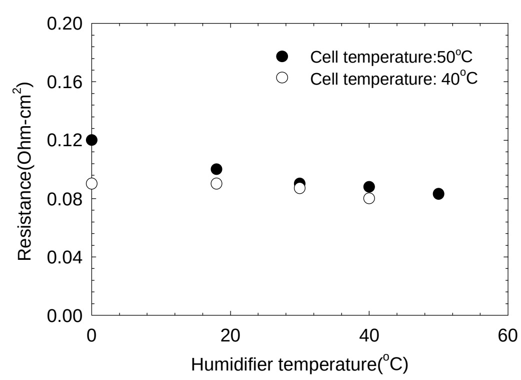

Figure 1. Effect of Relative Humidity on Nafion-Teflon-$Zr(HPO_4)_2$ Membrane Resistance. Membrane thickness: 0.7mil